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⑯ Crosslinkable flame retardant composition of polyphenylene ether and elastomers.

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⑯ Flame retardant mixtures of a polyphenylene ether resin,
an alkenyl aromatic elastomer, an organic phosphate flame
retardant agent and a crosslinking agent are described. They
are curable by heating or by exposure to high energy
radiation. Articles such as electrical wires and cables com-
prising insulation made of the composition, and a method of
their production, are also disclosed.

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CROSSLINKABLE FLAME
RETARDANT COMPOSITION
OF POLYPHENYLENE ETHER
AND ELASTOMERS

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BACKGROUND OF THE INVENTION

The polyphenylene ether resins are a family of engineering thermoplastics known to be useful with other polymers such as alkenyl aromatic resins to form compositions which are extrudable and moldable into various articles of commerce. The polyphenylene ether resins are described in the patent literature, for example, in U.S. Patent Nos. 3,306,874 and 3,306,875 (Hay), and U.S. Patent Nos. 3,257,357 and 3,257,358 (Stamatoff). Blends of polyphenylene ether resin and styrene polymers are disclosed by Cizek in U.S. Patent No. 3,383,435.

It is also known that polyphenylene ether resin blends can be made more flame retardant by the addition of agents effective for that purpose. Flame retardant polyphenylene ether - polystyrene compositions are described, for instance, in U.S. Patent No. 4,203,931, Lee, Jr., in which a halogenated aromatic, for example, tetrabromobenzene, is proposed as a suitable agent; and in U.S. Patent No. 4,355,126, Haaf, et al., in which aromatic phosphates and halogenated aromatics are listed. All of these compositions are thermoplastic by nature, being softened upon heating followed by hardening when cooled.

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SUMMARY OF THE INVENTION

The discovery has now been made of a crosslinkable, flame retardant composition of a polyphenylene ether resin, an alkenyl aromatic elastomer, an organic phosphate and a crosslinking agent, optionally also containing

a flame retardant brominated compound or polymer. The composition can be crosslinked (i.e., cured) by exposure to elevated temperatures, for example, about 300°F. or higher, or to high energy radiation, for example, high energy electrons. The cured material is characterized by decisively better tensile elongation and strength than the corresponding composition without the crosslinking agent.

The invention also comprises, in its other aspects, electrically conductive articles, such as wires and cables, containing insulation prepared from the above-described composition, as well as processes for producing such articles.

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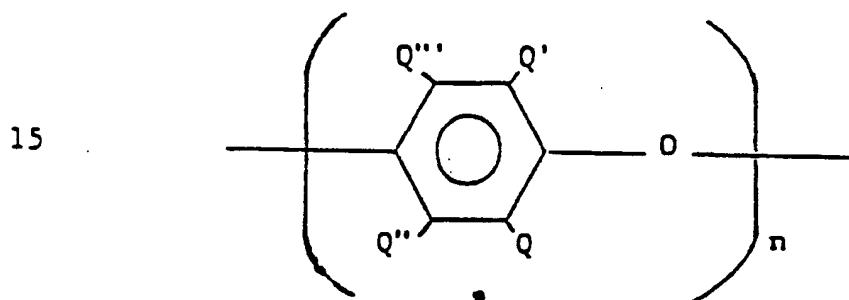
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DESCRIPTION OF THE INVENTION

The composition of this invention comprises, in its broadest features, an admixture of (a) a polyphenylene ether resin, (b) an alkenyl aromatic elastomer, 5 (c) an effective amount of an organic phosphate flame retardant agent, and (d) an effective amount of a cross-linking agent.

Preferred for use as the polyphenylene ether resin, component (a)(i), are homopolymers and copolymers 10 having units of the formula



20 wherein Q, Q', Q''' and Q'', are independently selected from the group consisting of hydrogen, halogen, hydrocarbon radicals, halohydrocarbon radicals, hydrocarbonoxy radicals, and halohydrocarbonoxy radicals; and n represents the total number of monomer units and is an 25 integer at least about 20, and preferably at least 50.

In general, the polyphenylene ether resins are self-condensation products of monohydric monocyclic phenols produced by reacting the phenols with oxygen in the presence of complex metal catalysts, with molecular 30 weight being controlled by reaction time, longer times providing a higher average number of repeating units. Particular procedures are known to those skilled in the art and are described in the patent literature, including U.S. Patent Nos. 3,306,874 and 3,306,875 (to Allan 35 Hay), and U.S. Patent Nos. 3,257,357 and 3,257,358

(to Gelu Stamatoff).

Illustrative polymers which can be produced by such procedures and which are within the above general formula are: poly(2,6-dilauryl-1,4-phenylene)ether; poly(2,6-diphenyl-1,4-phenylene)ether; poly(2,6-dimethoxy-1,4-phenylene)ether; poly(2,6-diethoxy-1,4-phenylene)ether; poly(2-methoxy-6-ethoxy-1,4-phenylene)ether; poly(2-ethyl-6-stearyloxy-1,4-phenylene)ether; poly(2,6-dichloro-1,4-phenylene)ether; poly(2-methyl-6-phenyl-1,4-phenylene)ether; poly(2,6-dibenzyl-1,4-phenylene)ether; poly(2-ethoxy-1,4-phenylene)ether; poly(2-chloro-1,4-phenylene)ether; poly(2,6-dibromo-1,4-phenylene)ether; and the like.

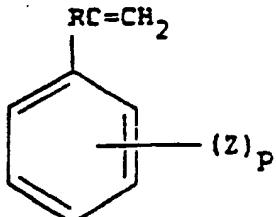
Also included are polyphenylene ether copolymers such as copolymers of 2,6-dimethylphenol with other phenols, for example, with 2,3,6-trimethylphenol or 2-methyl-6-butylphenol, etc.

For purposes of the present invention, an especially preferred family of polyphenylene ethers include those having an alkyl substitution in the two positions ortho to the oxygen ether atom, i.e., those of the above formula wherein Q and Q' are alkyl, most preferably having from 1 to 4 carbon atoms. Illustrative members of this class are: poly(2,6-dimethyl-1,4-phenylene)ether; poly(2,6-diethyl-1,4-phenylene)ether; poly(2-methyl-6-ethyl-1,4-phenylene)ether; poly(2-menthyl-6-propyl-1,4-phenylene)ether; poly(2,6-dipro-
25 pyl-1,4-phenylene)ether; poly(2-ethyl-6-propyl-1,4-phenylene)ether; and the like.

The most preferred polyphenylene ether resin for purposes of the present invention is poly(2,6-dimethyl-1,4-phenylene)ether.

The alkenyl aromatic elastomer, component (b) of the composition, is preferably a co- or terpolymer having at least some units derived from an alkenyl aromatic monomer of the formula

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where R is hydrogen, alkyl of from 1 to 4 carbon atoms or halogen; Z is vinyl, hydrogen, halogen, or alkyl of from 1 to 4 carbon atoms; and p is from 1 to 5.

15 Falling within the above formula are styrene and its homologs and analogs, including alpha-methyl styrene, para-methyl styrene, bromostyrene, chlorostyrene, xylene, vinyl toluene, vinyl xylene, ethyl vinyl xylene, vinyl naphthalene, and the like, individually or in various admixtures of two or more.

20 Illustratively, component (b) can be an elastomeric copolymer or terpolymer of an alkenyl aromatic compound and an elastomeric precursor such as a diene, for example, styrene-butadiene copolymers or

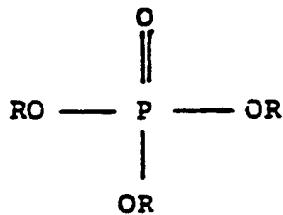
25 styrene-isoprene copolymers, styrene-butadiene-styrene or styrene-isoprene-styrene terpolymers, including hydrogenated derivatives such as styrene-ethylene/butylene copolymers and styrene-ethylene/butylene-styrene terpolymers, to name the most preferred materials. Mixtures of two or more of any of the foregoing are permissible. Still others will also occur to those skilled in the art, from among the many

alkenyl aromatic elastomers which are available or have been described in the literature.

The organic phosphate, component (c) of the composition, is preferably an aromatic phosphate

5 compound of the formula

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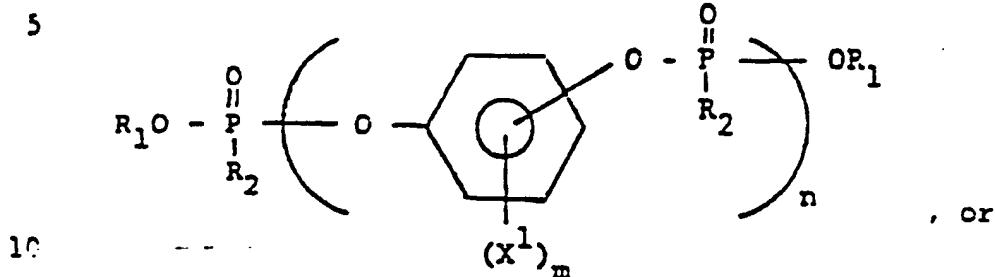
15 where R is the same or different and is alkyl, cyclo-alkyl, aryl, alkyl substituted aryl, halogen substituted aryl, aryl substituted alkyl, halogen, or a combination of any of the foregoing, provided at least one R is aryl.

20 Examples include phenyl bisdodecyl phosphate, phenylbisneopentyl phosphate, phenyl-bis(3,5,5'-trimethyl-hexyl phosphate), ethyldiphenyl phosphate, 2-ethyl-hexyldi(p-tolyl) phosphate, bis-(2-ethylhexyl) p-tolylphosphate, tritolyl phosphate, bis-(2-ethylhexyl)

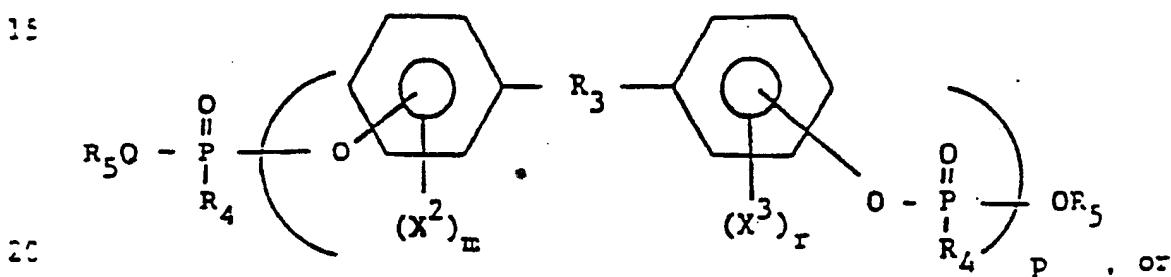
25 phenyl phosphate, tri-(nonylphenyl) phosphate, di(dodecyl)p-tolyl phosphate, tricresyl phosphate, triphenyl phosphate, dibutylphenyl phosphate, 2-chloroethylidiphenyl phosphate, p-tolyl bis (2,5,5'-trimethylhexyl)phosphate, 2-ethylhexyldiphenyl phosphate, 30 and the like. The preferred phosphates are those in which each R is aryl. Especially preferred is triphenyl phosphate, which may be either unsubstituted or substituted, for example, isopropylated triphenyl phosphate.

Alternatively, the organic phosphate can be a di- or polyfunctional compound or polymer having the formula

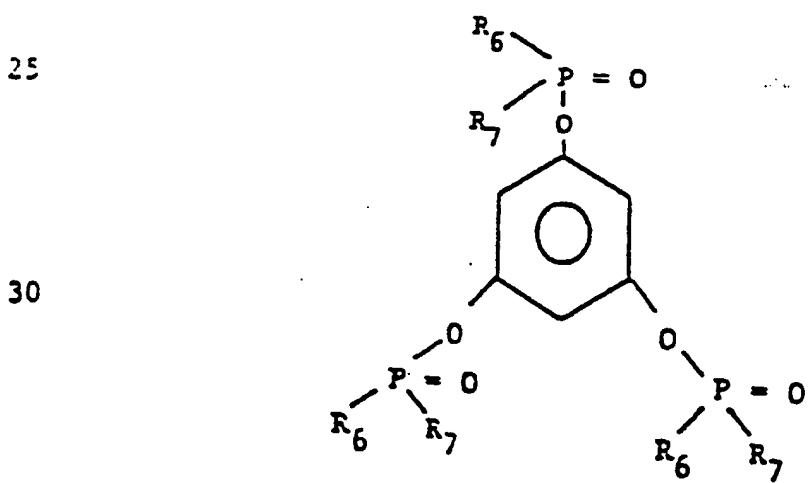
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including mixtures thereof, in which R_1 , R_3 and R_5 are, independently, hydrocarbon; R_2 , R_4 , R_6 and R_7 are, independently, hydrocarbon or hydrocarbonoxy; X^1 , X^2 and X^3 are halogen; m and r are 0 or integers from 1 to 4, 5 and n and p are from 1 to 30.

Examples include the bis diphenyl phosphates of resorcinol, hydroquinone and bisphenol-A, respectively, or their polymeric counterparts.

Methods for the preparation of the aforementioned di- and polyfunctional aromatic phosphates are 10 described in British Patent No. 2,043,083.

The polyphenylene ether, component (a), and the elastomer, component (b), are admixable in widely variant amounts, for example, in a weight ratio of 15 from 20:1 to 1:20.

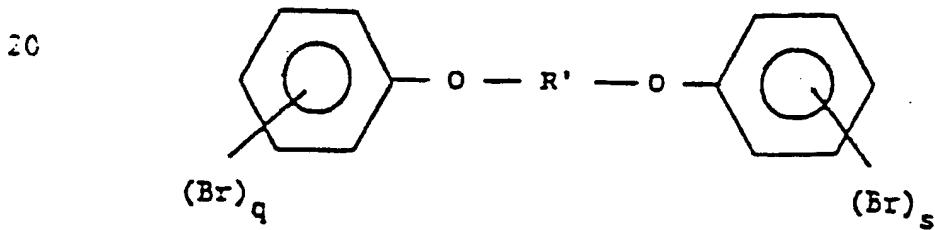
The organic phosphate is added in amounts effective to improve the flame retardancy of (a) and (b). Illustratively, concentrations of from 1 to about 30 parts by weight for each 100 parts of (a) 20 and (b), combined, are useful.

The composition is also modified to be thermosetting, that is, heat curable, or radiation curable by including one or more compounds, as component (d), effective to cause crosslinking when the composition is 25 exposed to an elevated temperature, for example, about 300°F. or higher, or to high energy radiation, for a relatively brief period of time. Preferably, the crosslinking agent has a low volatility at the temperatures employed for processing, as well as good stability in 30 the presence of the other ingredients of the composition. Special mention is made of organic peroxides, for example, dicumyl peroxide; 2,5-dimethyl-2,5-di(tert-butylperoxy) hexane; 2,2'-bis(t-butylperoxy)-diisopropyl benzene;

ethyl 3,3-bis(t-butyperoxy)butyrate; n-butyl-4,4-bis (4-butyperoxy)valerate; and 2,5-dimethyl-2,5-di (t-butyperoxy)hexane-3. Amounts of from about 1.5 to about 10 parts by weight of the crosslinking agent, for each 100 parts of (a) and (b) combined, are generally sufficient to provide the desired crosslinking.

The composition optionally can also include
10 (e) a stable brominated flame retardant material,
which can be an additional component of the
composition if desired. This ingredient can
be a brominated compound, or oligomer, or polymer that
is reasonably stable at elevated temperatures,
particularly those temperatures above 100°C., and,
15 moreover, is relatively nonvolatile at about
100° C.

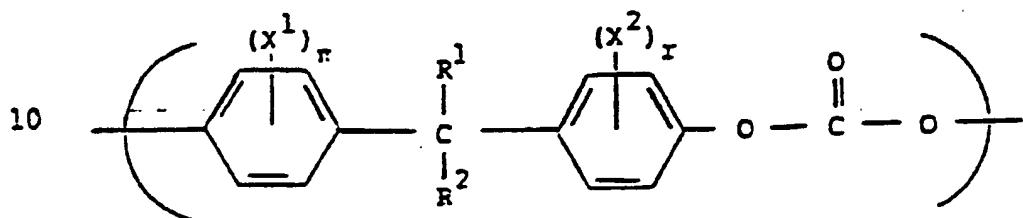
In the most preferred cases, this optional ingredient is a bis phenoxyl alkane of the formula



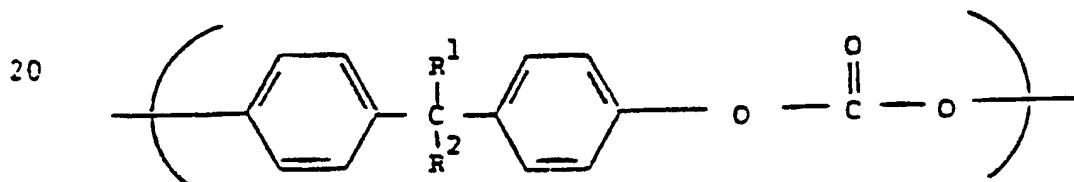
25 where R' is alkylene, straight or branched, having from 1 to 10 carbon atoms, and, more preferably, from 1 to about 6 carbon atoms; and q and s represent the total number of bromine atoms on each ring and are, independently, integers from 1 to 5.

30 Examples are 1,2-bis(2,4,6-tribromophenoxy)ethane; 1,3-bis(2,4,6-tribromophenoxy)propane; 1,4-bis(2,4,6-tribromophenoxy)butane; and 2,2-bis(4-bromophenoxy)propane. Preferred are 1,2-bis(2,3,4,5,6-pentabromophenoxy)ethane. A method of preparation is
35 described in U.S. Patent No. 4,016,138 (Anderson).

Also useful are brominated oligomeric or polymeric flame retardants, including those which are described in U.S. Patent No. 3,334,154 (Kim) and U.S. Patent No. 3,833,685 (Wambach). For example, these 5 can be aromatic carbonate copolymers having units of the formula



15 in which R¹ and R² are hydrogen, (lower) alkyl or phenyl, X¹ and X² are bromo or chloro, and m and r are from 1 to 4, and units of the formula



25 in which R¹ and R² are as defined above.

Especially preferred, however, are oligomeric tetrabromobisphenol-A polycarbonates.

Amounts of from 0 to about 30 parts by weight for each 100 parts of (a)(i) and (a)(ii) together are 30 preferred.

The brominated additive can be used alone, or together with a synergistic agent such as an antimony or molybdenum compound. The synergist can be selected from among those compounds based on the aforementioned 35 elements which are known to improve the effectiveness of

brominated flame retardants. Among these, antimony oxide is especially preferred for use in this invention, usually in amounts from about 1 to about 10 parts by weight per 100 parts of (a) and (b).

5 The composition may be prepared in any convenient manner, such as by forming a mixture of components (a), (b), (c) and (d), and any other ingredients, extruding the mixture at an elevated temperature, and then processing into the shaped article, as by molding.

10 A particular application involves the use of the composition in the manufacture of insulation material for electrically conductive articles, for example, copper or aluminum wires and cables. A method of use comprises providing the described

15 composition and applying it to the surface of an electrically conductive metal article; thermosetting or radiation curing can take place before application, or in situ on the metal article. The insulated article can additionally comprise an outer protective coating,

20 which can be made of a thermoplastic or thermosetting polymer, e.g., polyvinyl chloride. Exemplary products are shown in the accompanying drawings, which are described below.

25 BRIEF DESCRIPTION OF DRAWINGS

Figure 1 illustrates an electrically conductive article in accordance with the invention, in cross-section, comprising copper wire 2, and insulation layer 4, consisting of a flame retardant

30 composition as described above.

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Figure 2 illustrates a modified embodiment, also in cross-section, comprising copper wire 2, flame retardant insulation layer 4, and outer protective polymeric coating 6.

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DESCRIPTION OF THE SPECIFIC EMBODIMENTS

The invention is illustrated in the following examples, which are intended to show merely some of the embodiments possible. All amounts are 10 stated in parts by weight.

EXAMPLES 1-4

Thermosetting compositions in accordance with the invention were prepared using the ingredients 15 noted in 2 and 4 below. The blends were compression molded at 360°F. for 10 minutes to effect curing. For comparison purposes, thermoplastic blends 1 and 3 were compression molded at 360°F., for 45 minutes.

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TABLE I

INGREDIENTS, parts by weight	1	2	3	4
Styrene-butadiene rubber	30	10	40	40
Poly(2-6-dimethyl-1,4-phenylene) ether resin	45	45	10	30
Elastomeric styrene-ethylene/butylene-styrene block copolymer (SEBS)	30	30	20	20
Isopropylated triphenyl phosphate	15	15	10	10
Antioxidant	1	1	1	1
α,α' -bis(t-butylperoxy)diisopropylbenzene crosslinking agent	--	2	--	2
PROPERTIES				
Tensile strength, psi	310	470	315	530
Elongation, %	85	200	70	240
Vertical Burn Test, 1/8 inch specimen:				
Drip characteristics	ND	ND	ND	ND
Seconds to quench				
1st ignition	>10, >30	10, 11	>10, >30	14, 46
2nd ignition	--	>10, >30	--	37, 47
				124

* Precompounded by extrusion at 500-600°F.

ND = No drip

EXAMPLES 5-8

Additional thermosetting compositions in accordance with the invention, and thermoplastic comparisons, were prepared with the ingredients 5 listed below. Compositions 5 and 7 were compression molded at 360°F., for 45 minutes. Compositions 6 and 8 were compression molded at 360°F., for 10 minutes, to effect cure.

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TABLE 2

INGREDIENTS, parts by weight	5	6	7	8
Elastomeric styrene-ethylene/ butylene-styrene block copolymer	30	30	40	40
Poly(2,6-dimethyl-1,4-phenylene) ether resin	45	45	30	30
Elastomeric styrene-ethylene/ butylene-styrene block copolymer	30	30	20	20
Isopropylated triphenyl phosphate	15	15	10	10
Antioxidant	1	1	1	1
α, α' -bis(t-butylperoxy)diisopropyl benzene crosslinking agent	--	2	--	2
PROPERTIES				
Tensile strength, psi	345	620	360	650
Elongation, %	90	190	60	200
Vertical Burn Test, 1/8"				
Drip characteristics	ND	ND	ND	ND
Seconds to quench				
1st ignition	9,10	3,5	12,14	6,8
2nd ignition	730, 30	16,20	730, 30	21,24

* precompounded by extrusion at 500-600°F.
ND - No drip

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All of the above mentioned patents and publications are incorporated herein by reference.

Other modifications and variations of the invention are possible and will occur to those skilled 5 in the art in light of the above disclosure. It is to be understood, therefore, that changes may be made in the particular embodiments shown without departing from the spirit of the invention or its scope as defined in the appended claims.

10 The composition can be further modified, for instance, by including one or more additives often used with thermoplastic polymers, some of which may serve to beneficially affect the chemical and physical properties. Examples are mineral fillers, 15 including clay, reinforcing agents, for example, glass fibers, flakes or spheres, plasticizers, stabilizers, antioxidants, colorants, processing aids, and so forth, in conventional amounts.

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CLAIMS:

1. A heat or radiation curable flame retardant composition, comprising an admixture of

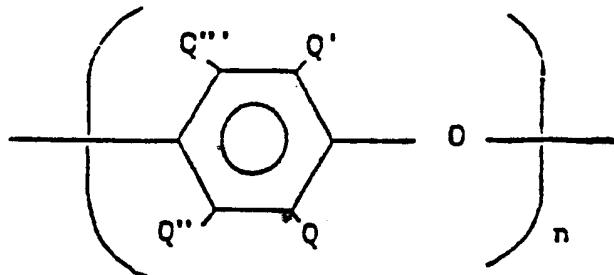
(a) a polyphenylene ether resin;

5 (b) an alkenyl aromatic elastomer;

(c) an effective amount of an organic phosphate flame retardant agent; and

(d) an effective amount of a crosslinking agent.

10 2. A composition according to Claim 1, in which (a) is a homopolymer or copolymer having units of the formula



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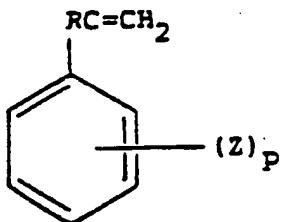
wherein Q, Q', Q'' and Q''' are independently selected from the group consisting of hydrogen, halogen, hydrocarbon radicals, halohydrocarbon radicals, hydrocarbon-oxy radicals, and halohydrocarbon-oxy radicals; and n represents the total number of monomer units and is an integer at least about 20.

25 3. A composition according to Claim 1, in which (a) is poly(2,6-dimethyl-1,4-phenylene ether).

4. A composition according to Claim 1, in 30 which (b) is an elastomeric copolymer or terpolymer of an alkenyl aromatic compound.

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5. A composition according to Claim 4, in which at least a portion of the units of (b) are derived from an alkenyl aromatic monomer of the formula



where R is hydrogen, alkyl of from 1 to 4 carbon atoms or halogen; Z is vinyl, hydrogen, halogen or alkyl of from 1 to 4 carbon atoms; and p is from 1 to 5.

6. A composition according to Claim 1, in
15 which (b) is a styrene-butadiene rubber.

7. A composition according to Claim 1, in which (b) is a styrene-ethylene/butylene-styrene block copolymer.

8. A composition according to Claim 1, in
20 which (c) is an aromatic phosphate of the formula

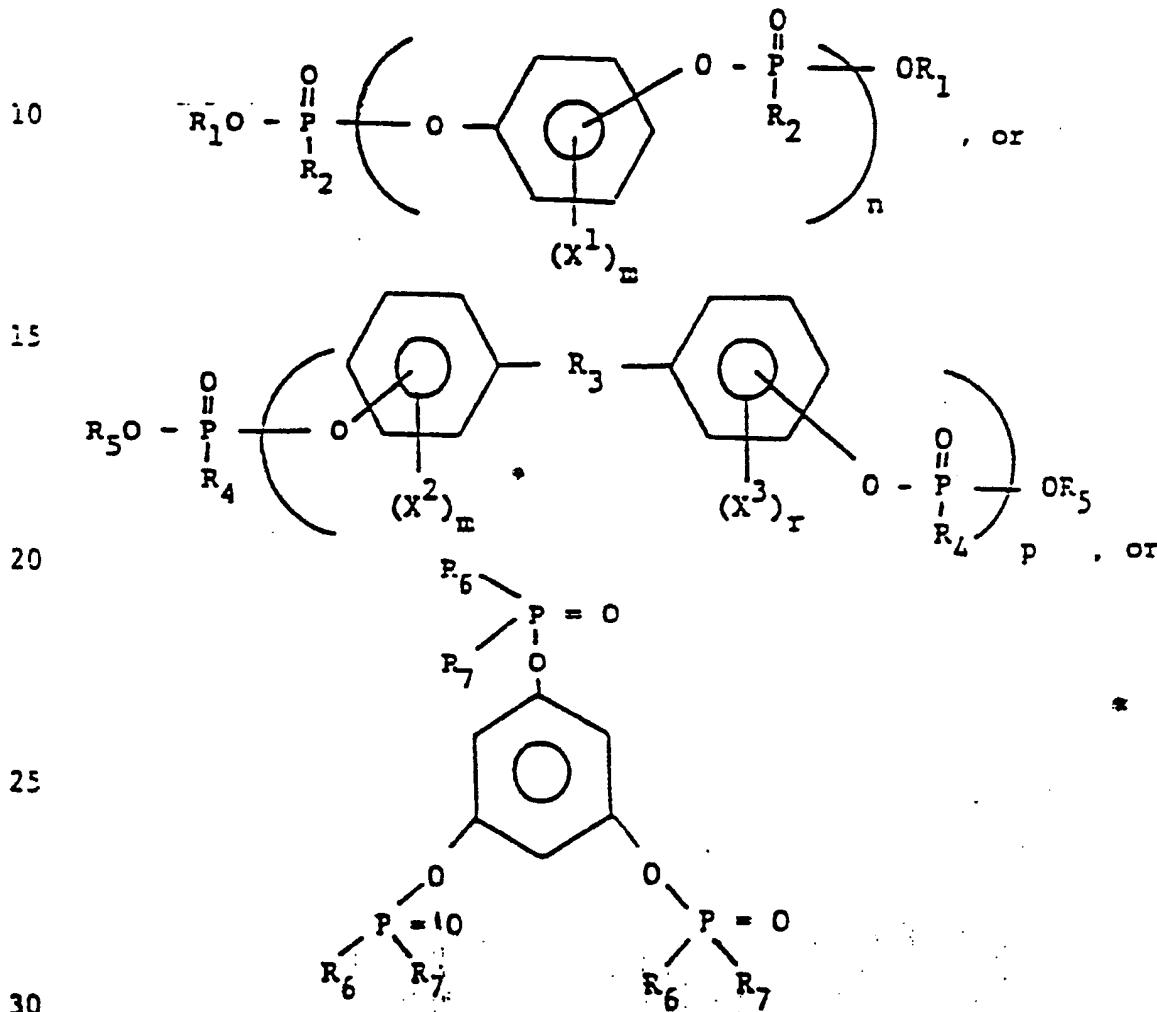


where R is the same or different and is alkyl, cyclo-
30 alkyl, aryl, alkyl substituted aryl, halogen substituted aryl, aryl substituted alkyl, halogen, or a combination of any of the foregoing, provided at least one R is aryl.

9. A composition according to Claim 8, in which the aromatic phosphate is triphenyl phosphate.

10. A composition according to Claim 9, in which the triphenyl phosphate is isopropylated.

5 11. A composition according to Claim 1, in
which (c) is a di- or polyfunctional compound
or polymer of the formula



including mixtures thereof, in which R_1 , R_3 and R_5 are, independently, hydrocarbon; R_2 , R_4 , R_6 and R_7 are, independently, hydrocarbon or hydrocarbonoxy; X^1 , X^2 and X^3 are halogen; m and r are 0 or integers from 1 to 4, and n and p are from 1 to 30.

12. A composition according to Claim 11, in which (c) is a bis diphenyl phosphat of resorcinol.

13. A composition according to Claim 11, in which (c) is a bis diphenyl phosphate of hydroquinone.

5 14. A composition according to Claim 11, in which (c) is a bis diphenyl phosphate of bisphenol A.

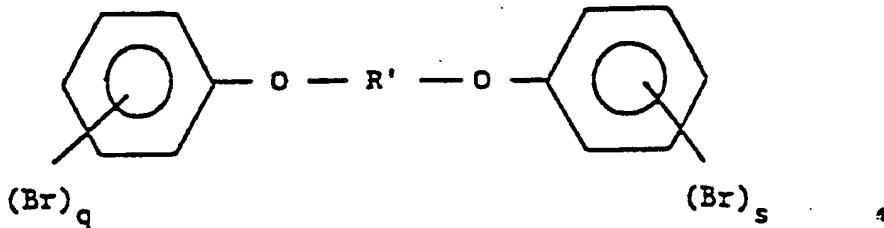
15. A composition according to Claim 1, in which (d) is an organic peroxide.

16. A composition according to Claim 15, in 10 which (d) is a, a'-bis(tert-butyl peroxy) diisopropyl benzene.

17. A composition according to Claim 1, which also includes (e) a stable brominated flame retardant material, in an amount sufficient to enhance 15 the flame retardancy of (c).

18. A composition according to Claim 17, in which (e) is a bis phenoxy alkane of the formula

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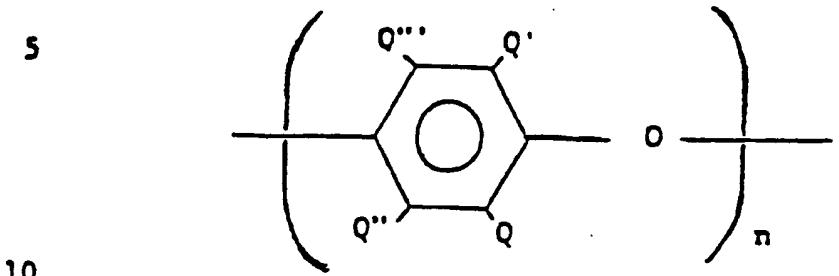


25 where R' is alkylene, straight or branched, having from 1 to 10 carbon atoms, and, more preferably, from 1 to about 6 carbon atoms; and q and s represent the total number of bromine atoms on each ring and are, independently, integers from 1 to 5.

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19. A composition according to Claim 18, in which (e) is 1,2-bis(2,4,6-tribromphenoxy) ethane.
20. A composition according to Claim 18, in which (e) is 1,2-bis(2,3,4,5,6-pentabromphenoxy) 5 ethane.
21. A composition according to Claim 17, in which (e) is an oligomeric tetrabromobisphenol A polycarbonate.
22. A composition according to Claim 17, 10 which further includes a synergistic agent for (e).
23. A composition according to Claim 22, in which the synergist is an antimony compound.
24. A composition according to Claim 23, in which the antimony compound is antimony oxide.
- 15 25. A composition according to Claim 1, in which the weight ratio of (a) to (b) is from 20:1 to 1:20.
26. A composition according to Claim 1, which comprises from 1 to about 30 parts by weight of 20 (c) and from about 1 to about 10 parts by weight of (d), for every 100 parts of (a) and (b) together.
27. An electrically conductive article, comprising a metallic conductor, at least a portion of the surface of which is covered with an electrically 25 insulating layer of a flame retardant composition comprising an admixture of
 - (a) a polyphenylene ether resin;
 - (b) an alkenyl aromatic elastomer;
 - (c) an effective amount of an organic30 phosphate flame retardant agent; and
 - (d) an effective amount of a crosslinking agent.

28. An article according to Claim 27, in which (a) is a homopolymer or copolymer having units of the formula



wherein Q, Q', Q'' and Q''', are independently selected from the group consisting of hydrogen, halogen, hydrocarbon radicals, halohydrocarbon radicals, hydrocarbon-oxy radicals, and halohydrocarboxy radicals; and n represents the total number of monomer units and is an integer at least about 20.

15 29. An article according to Claim 27, in which (a) is poly(2,6-dimethyl-1,4-phenylene ether).

30. An article according to Claim 27, in which (b) is a styrene copolymer or terpolymer.

20 31. An article according to Claim 27, in which (b) is a styrene-ethylene-butylene-styrene terpolymer.

32. An article according to Claim 27, in which (b) is an aromatic phosphate compound.

25 33. An article according to Claim 27, in which (c) is triphenyl phosphate.

34. An article according to Claim 33, in which the triphenyl phosphate is isopropylated.

30 35. An article according to Claim 27, in which (c) is a bis diphenyl phosphate of resorcinol, hydroquinone or bisphenol A.

36. An article according to Claim 27, in which (d) is an organic peroxide.

37. An article according to Claim 36, in which (d) is a, a'-bis(tert-butyl peroxy) diisopropyl 5 benzene.

38. An article according to Claim 27, in which the flame retardant composition includes (e) a stable brominated flame retardant material in a flame retardancy enhancing amount.

10 39. An article according to Claim 38, in which (e) is a brominated bisphenoxy alkane.

40. An article according to Claim 39, in which (e) is 1,2-bis(2,4,6-tribromophenoxy) ethane.

15 41. An article according to Claim 39, in which (e) is 1,2-bis(2,3,4,5,6-pentabromophenoxy) ethane.

42. An article according to Claim 38, in which (e) is an oligomeric tetrabisphenol A polycarbonate.

20 43. An article according to Claim 27, in which the flame retardant composition has been cured by exposure to high energy electrons.

44. An article according to Claim 27, in which the flame retardant composition has been cured 25 by exposure to heat.

45. In a method for preparing an electrically conductive article, the improvement comprising using as insulation material a curable flame retardant composition comprising an admixture of

30 (a) a polyphenylene ether resin;

(b) an alkenyl aromatic elastomer;

(c) an effective amount of an organic phosphate flame retardant agent; and

(d) an effective amount of a crosslinking agent.

46. A method according to Claim 45, in which
(a) is poly(2,6-dimethyl-1,4-phenylene ether).

47. A method according to Claim 45, in which
(b) is a styrene-butadiene rubber.

5 48. A method according to Claim 45, in which
(b) is a styrene-ethylene/butylene-styrene copolymer.

49. A method according to Claim 45, in which
(d) is an organic peroxide.

50. A method according to Claim 49, in which
10 (d) is a, a'-bis(tert-butyl peroxy) diisopropyl benzene.

51. A method according to Claim 45, in which
the flame retardant composition further includes (e) a
stable brominated flame retardant material.

52. A method according to Claim 51, in which
15 (e) is a brominated bisphenoxyl alkane.

53. A method according to Claim 51, in which
(e) is an oligomeric tetrabromobisphenol A polycarbonate.

54. A method according to Claim 45, in which
(c) is isopropylated triphenyl phosphate.

20 55. A method according to Claim 45, in which
the flame retardant composition has been cured by expo-
sure to radiation.

56. A method according to Claim 45, in which
the flame retardant composition has been cured by
25 exposure to heat.

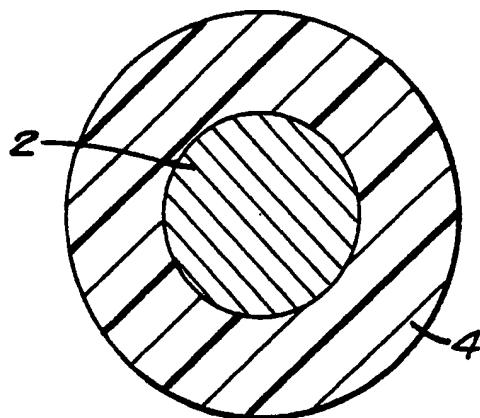


FIG. 1

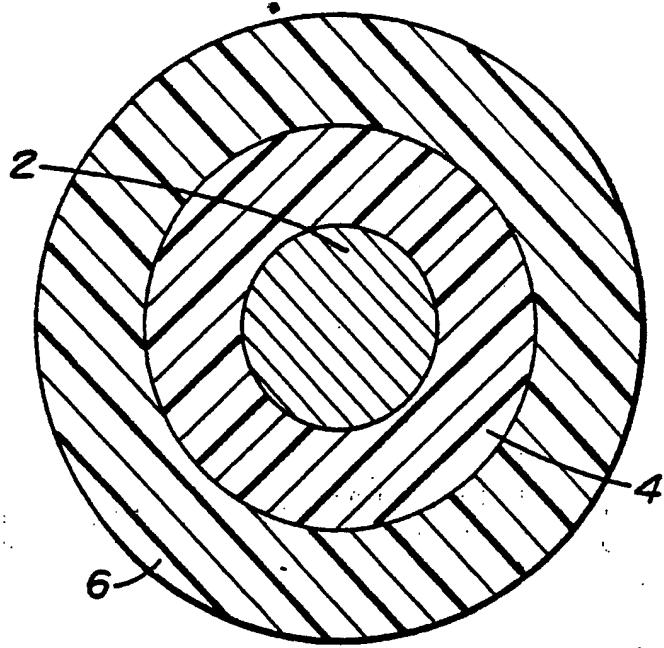


FIG. 2